RADIATION AND POLARIZATION MEASUREMENTS DURING THE SOLAR ECLIPSE OF APRIL 8, 1921, AT DAVOS

By C. DORNO

The following note was sent to the Solar Radiation Investigations Section of the Weather Bureau by Doctor Dorno, with the comment that "The interest which was taken in the solar eclipse of the 24th of January, 1925, was so great in the United States that perhaps the hitherto unpublished observations conducted here on that of the 8th of April, 1921, will also be found worth attention." Slight changes have been made in the text, the original figures of course remaining unaltered.

Commencement of the eclipse, $8^h.175$

Maximum obscuration, $9^h.430$

End of the eclipse, $10^h.783$

Maximum obscuration, 0.738 solar diameter, or 0.663 solar area.

Cloudiness, during first half of eclipse 3–4 Fr.–Cu.; later 0.

Radiation.—At the time of maximum obscuration, a decrease was found as follows:

	Per cent
In the total intensity	73. 0
In the intensity of the red rays (measured with Michelson's actinometer in single readings)	70. 8
In the intensity of the ultra-violet (measured with cadmium cell)	77. 4
In the total intensity of sun plus sky (registered with Ångström's pyranometer)	66. 8

The decrease and increase occurred unsymmetrically with the chief phase as follows:

In total intensity	decrease slower than increase;
In red intensity	decrease slower than increase;
In ultra-violet intensity	decrease more rapid than increase;
In sun plus sky intensity	decrease more rapid than increase.

The percentage of decrease of radiation is greater than the percentage of obscured surface, for the reason that at the maximum phase a relatively large part of the unobscured solar surface was near the solar margin, and only a small part consisted of the strongly radiating center of the sun's disk. The decrease of brightness from the center to the margin of the solar disk is greater for ultra-violet than for red; therefore, the measurements give a greater decrease of radiation in the ultra-violet than in the red. From the distribution of brightness over the solar disk for wave length 0.644 (red) determined by C. G. Abbot[1] and for ultra-violet, 0.320 (approximate optic center of gravity of cadmium cell) by Schwarzschild and Villiger,[2] a loss of radiation is calculated from the surface obscuration of 74.7 per cent of red, and 81 per cent for ultra-violet, i. e., 3.9 per cent for red and 3.6 per cent for ultra-violet more than found. The diffraction of rays round the edge of the obscuring disk of the moon necessitates a difference in the direction measured, and this must be somewhat greater for red than for ultra-violet, as the diffracted light arises from the marginal zones which are relatively rich in red.

According to the visual observations made, the velocity of travel of the shadow from 25 minutes before until 25 minutes after the maximum appears to have been approximately the same, and the total duration of the increase is about seven minutes longer than that of the decrease. Both these observations are in agreement with the variations in the ultra-violet radiation which, owing to the quartz optical system employed, was exclusively of solar-origin. On the other hand, in conformity with the construction of Michelson's actinometer, the values for the total and red radiation include a zone of the sky which extends to about 5 degrees around the sun; therefore their radiation values exhibit slightly different changes.

Polarization.—The amount of polarization of the zenith undoubtedly increased during the eclipse, as a comparison with the normal spring values belonging to the corresponding solar altitudes proves. The course of the Babinet point is not distinct; during the first half of the eclipse it appeared to approach the sun, while its course during the second half casts doubt upon this conclusion.

Meteorological elements.—Temperatures measured with Assman's aspiration psychrometer distinctly show a fall of the wet bulb as well as of the dry bulb thermometers, which reaches a maximum at the time of maximum eclipse. The relative humidity derived from these temperatures shows no reversion, although an interruption of the normal daily decrease sets in shortly after the maximum eclipse phase. The atmospheric pressure fell slowly and continuously from morning until noon, the total fall amounting to 0.8 mm.

[1] Annals of the Astrophysical Observatory, III, p. 157.

[2] Physikalische Zeitschrift, 1905, p. 742.

SEASONAL PRECIPITATION IN CALIFORNIA AND ITS VARIABILITY

By B. M. VARNEY

PART II

V. MEAN SEASONAL DEPARTURES FROM MEAN SEASONAL RAINFALL IN CALIFORNIA

1. *Selection of stations as a basis for mapping.* The mapping and discussion of the mean seasonal departures have been based on the records of the 82 stations which at the end of the 1919–20 season had 25 seasons of record. The reasons for thus limiting the basis for the treatment of this phase of the subject are three: First, it is preferable to compute departures on the basis of means derived from the actual number of seasonal totals available for the station in question, and not on adjusted means. Second, means based on short periods may not be at all representative of the true conditions. Third, the small number of departures available in the short records make any computation of mean departures from seasonal averages in terms of percentage of those averages highly illusory.

The resulting restriction of the number of records that can justifiably be used leads to unsatisfactory distribution of the stations for mapping purposes. The situation is made clear by reference to Figures 1 (see part 1 of this paper, in REVIEW for April, 1925) and 5, the first of which, together with the alphabetical and numerical lists of stations in Table 3 (in part I of this paper), forms a guide to the stations used, and the second of which shows the distribution of percentage departures for those stations. Points that will be noted in regard to station distribution are: First, the high concentration of stations in the north central part of the State, and the moderate concentration in southern California; second, the very cattered distribution in the north, in the deserts, in the Coast Ranges, and along the coast, except where the last two regions are affected by the concentration in the north central area; third, the fact that the Sacramento Valley is much more adequately represented than the San Joaquin.

In spite of this admittedly poor distribution of stations, certain broad facts may be deduced from the map (fig. 5) and from the dot chart (fig. 6). These will now be briefly noted.

2. *Relation of departures to altitude.*—Referring first to the chart, the departures in percentages of the mean seasonal totals of rainfall at each of the 82 stations are there plotted with reference to the altitudes of their occurrence, ordinates representing altitudes and abscissae the amounts of percentage departure. The most striking facts shown are the concentration of the departures largely within the limits of 20 and 30 per cent, and the lack of clear relation of the departure to altitude. Table 8 serves to emphasize these facts. The first column

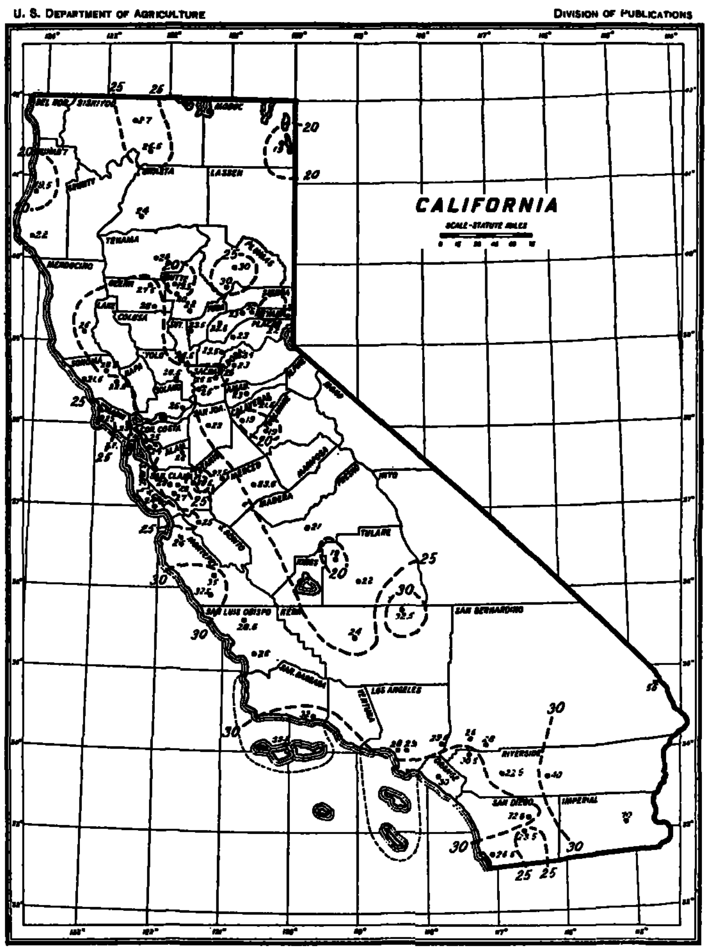

FIG. 5.—Average seasonal departures of precipitation in percentages of the seasonal average rainfall at stations having records of not less than 25 seasons ending 1919–20

divides the range of altitudes into thousand foot zones, the second give the number of stations within each zone, the third the spread between the greatest and least departures within each zone, and the fourth the mean of the departures within the zone.

3. *Discussion of the areal distribution of departures.*—The range of departures is not large. Nevertheless it is probably more significant than its size might suggest, on account of the wide differences in mean seasonal rainfall through which this moderate range of departures runs. That is to say, from the point of view of the influence of rainfall on vegetation, a mean departure of 25 per cent from a rainfall of 40 inches may mean quite different consequences from the same mean departure from a rainfall of 20 inches. In the first instance, minus departures rarely affect yields to a serious extent; in the second they may easily do so. This aspect of rainfall is of little importance in irrigated areas which are well

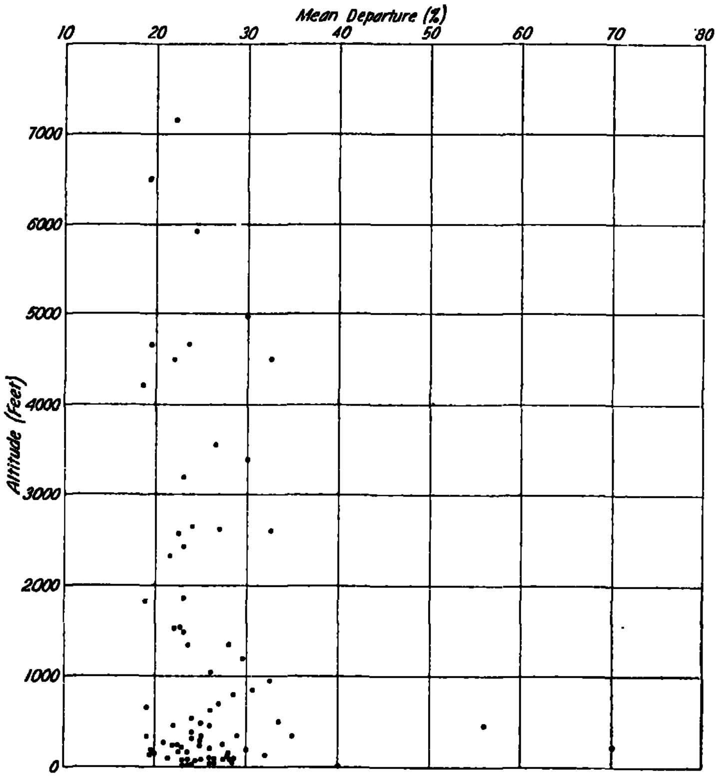

FIG. 6.—Relation between altitude and the average seasonal departures (in percentages of the seasonal average rainfall) for stations having not less than 25 seasons of record ending 1919–20

supplied with facilities for water storage; but on areas not well supplied and on nonirrigated lands, it may become of the greatest importance. This is particularly the case in the pasture region of the Coast Ranges where the tendency to a somewhat greater variability than obtains in the central agricultural region of the State is one cause of the occasional serious deficiency in the crop of wild grasses which results in great losses of cattle in the years of large minus departures.

TABLE 8.—*The relation between altitude and mean departures of seasonal precipitation from the average*

Altitude zones	Number of stations	Difference between greatest and least departures (per cent)	Mean of all departures (per cent)
Feet			
0–1,000	52	16	25.8
0–1,000	[1] 52+3	51	27.2
1,000–2,000	9	11	24.1
2,000–3,000	6	12	25.1
3,000–4,000	3	7	26.5
4,000–5,000	5	15	23.2
5,000–6,000	2	8	26.0
6,000–7,000	1		19.5
7,000–8,000	1		22.0

[1] Desert stations.

Within the small range of departures certain regions of the State stand out with considerable clearness, though in interpreting the map it should be borne in mind that except in regions where stations are close together, the location of the lines is highly provisional.

(a) *The region east of the Sacramento and San Joaquin Rivers.*—In general it may be said that so far as the stations indicate, the northeastern part of the Sacramento Valley, the eastern half of the San Joaquin Valley, and the whole of the Sierra Nevada (except locally in Plumas County) including the entire foothill region, has departures that average distinctly less than those of the major part of the Coast Ranges. As pointed out above there seems to be little basis for believing that departures either increase or decrease significantly with increase of altitude in this region. Locally they appear to. Thus from Stockton in the Valley close to sea level to Sonora at 1,825 feet altitude in the Sierra foothills, there is a decrease from 23 per cent to 19 per cent. This, however, is but the same decrease as that which takes place longitudinally in the San Joaquin Valley between Stockton in the north and Visalia in the south. On the other hand, three stations at successively higher altitudes in Calaveras County show values of 19 per cent, 22 per cent and 21.5 per cent, respectively, a net change too small to be of consequence. Along the Southern Pacific Railroad, Auburn at 1,360 feet has a mean departure of 23.5 per cent, Colfax at 2,421 feet 23 per cent, Summit at 7,017 feet 22 per cent, a change which is quite without significance. Between Nevada City at 2,580 feet and Fordyce Dam at 6,500 feet, a decrease from 22.5 per cent to 19.5 per cent is interrupted by the occurrence of a departure of 23 per cent at North Bloomfield (3,200 feet). Between Oroville at the base of the Sierra foothills in Butte County (250 feet) and La Porte in Plumas County (5,000 feet), the departure changes from 22 per cent to 30 per cent. No stations intermediate exist to show the nature of the transition. Altogether, the case for a decrease of variability with increasing altitude seems about as good as for an increase, and vice versa.

(b) *Comparison between the Sacramento and San Joaquin Valleys.*—The mean of all departures in the Sacramento Valley (14 in number) is 25 per cent, a departure appreciably higher than the mean of 22.9 for the seven stations in the San Joaquin. The latter mean is increased, moreover, by the value of 27.5 for Newman on the west side of the valley, that station having a departure which is characteristic of those in that part of the Coast Ranges lying to the west of the valley, apparently due to its nearness to the Coast Ranges. This variation from the typical valley condition is in accord with that seen in the western part of the Sacramento Valley throughout its length. In fact, if we take the mean of the seven stations in the eastern Sacramento Valley (east of the Sacramento River), we find it to be 23.1 per cent, or to all intents and purposes identical with that of the six stations in the San Joaquin, excluding Newman. The mean of the six west-side stations is 27.8 per cent (excluding Knight's Landing on the west bank of the river, which has a mean departure of 24.5 per cent, distinctly intermediate between those of the eastern and western areas). This mean of the west-side stations is essentially the same as that at Newman, the one station available for the western San Joaquin. For the whole Interior Valley, then, it may be said that departures average about 5 per cent greater in the western than in the eastern parts, and that longitudinally on either side the differences between the northwest end and the southeast are so small as to be without importance.

The extreme ends of the valley show perhaps the beginning of a transition to conditions which seem to be characteristically different from those in the eastern part of it. On the north there is a tendency toward increasing departures as one goes into the hill and mountain country. On the south, Bakersfield has a slightly higher mean departure than any of the east-side valley stations, 24 per cent, and Kernville at 2,600 feet altitude in the Tehachapi Range with a mean departure of 32.5 per cent shows an increase well above the valley stations, due probably either to increased elevation or to the fact that it is situated in the fringe of the great southeastern desert area of the State.

(c) *The southeastern desert.*—The southeastern desert has departures greater than any other region in California, culminating in the extraordinary value of 70 per cent of the mean seasonal rainfall at Sterling in the Imperial Valley. Needles, on the Colorado River, and Indio some 20 miles northwest of the Salton Sea, have departures which are only less remarkable. The statement of the mean departures, however, conveys little idea of the conditions. It may be noted that the extreme departures in this southeastern desert have little effect on agriculture because this is exclusively of the irrigation type. When there is an influence it is the adverse one of too much moisture, resulting in certain ill effects of dampness on commercial crops which are here normally exposed to extreme atmospheric dryness, and resulting occasionally also in damage to crops in process of harvesting and shipment. The writer has heard farmers in this region say: "We would rather it never rained."

(d) *The Coast Ranges and the coast.*—It was pointed out above that the departures in the western Sacramento and San Joaquin Valleys were similar to those in that part of the Coast Ranges lying to the west. This area of the Coast Ranges lies within the isogram of 25 per cent mean departure except for a coastal strip in the north along which the departures are considerably less. Averaging the 12 stations inclosed by this isogram, including 2 of over 30 per cent in Monterey County and excluding the 18.5 per cent for Mount Hamilton (for a reason that will be pointed out), we have 28.2 per cent, or essentially the same value as that found for the western part of the Interior Valley, and some 5 to 6 per cent higher than that of the eastern Interior Valley. There is little evidence of significant increase or decrease longitudinally in either direction within this area. Mount Hamilton clearly presents a divergence from the general condition. In this divergence, on account of which its departure was not included in the general average just given, it is comparable with San Jacinto Peak in southern California. Both mountains form the culminating and somewhat isolated summits of their respective highlands. It may be that their notably smaller average departures as compared with the surrounding lower country are in accordance with a law the existence of which could be demonstrated if we had enough records from similarly isolated peaks distributed throughout the State.

A relatively narrow zone along the outer coast from the Oregon line to Monterey Bay has, so far as indicated, departures somewhat smaller than those of the major part of the Coast Ranges adjacent. From the bay southeastward, however, departures are consistently higher than in the north, varying mostly within 3 per cent either way from 30 per cent of the mean seasonal rainfall. San Diego shows but 26.5 per cent.

(*e*) *Relation of mean seasonal departures to mean seasonal rainfall.*—An inspection of the map does not lead to the conclusion that mean percentage departures tend to vary consistently either directly or inversely with the amount of the mean seasonal rainfall. Departures in the San Joaquin Valley with its rainfalls of 5 to 10 inches, appear to be of the same order as those of the northwest coast where the rainfall is three to ten or more times as great. The southeastern desert shows departures of 40 to 70 per cent (three stations), while the northeastern semiarid region shows a departure of 19 per cent (one station). Stations along the coastal strip of southern California with rainfalls of 10 to 20 inches have mean departures approximating 30 per cent, while the same departures occur in Plumas County in the northern Sierra Nevada with rainfalls of 40 to 75 inches. Other comparisons leading to the same conclusion are evident from the map.

(*f*) *Summary.*—We may conclude from the above discussion that—

1. The eastern part of the Interior Valley and the Sierra in general show less variability than the western part of the valley and the Coast Ranges.
2. There appears to be no consistent increase or decrease of variability with increase of altitude in the Sierra.
3. The departures in the eastern part of the Interior Valley tend to increase toward the mountain or desert country north and south of them respectively.
4. The departures of the southeastern desert region are the most extreme in the State.
5. Along a narrow coastal zone, departures appear to be distinctly less in the northern half of the coast than in the southern.
6. The departures in the Coast Ranges average somewhat higher than those of the eastern Interior Valley and of the northern coastal zone, and do not change significantly from north to south along the ranges.
7. While there does not appear to be any strong relation between the amounts of mean percentage departure and the amount of the average seasonal rainfall, nor any clear evidence of a gradual increase in variability with decreasing latitude, nevertheless, speaking very broadly, the agricultural region of southern California west of the desert does show a somewhat greater variability than the major agricultural regions north of latitude 35 degrees.

VI. FREQUENCIES OF RAINFALLS OF CERTAIN AMOUNTS AT CALIFORNIA STATIONS

1. *Method of presenting rainfall frequencies in this section.*—For the purpose of depicting this aspect of California rainfall, it has been thought best to confine the graphic material to such as could be presented in diagram form (as distinguished from map form), and the examples to stations having 40 years of record or more. In the frequency computations which form the basis of the polygons in Figure 7, use has been made of the full length of the record in each case, and percentage frequencies (x) arrived at through the proportion:

$$\frac{\text{Actual frequency of stated seasonal amounts}}{\text{Number of seasons of record}}=\frac{x}{100\,\text{seasons}}.$$

By extending the records of a few stations through the season 1922–23 it has been possible to include a total of 43 stations, a number which allows a fair distribution areally, and a representation of each major topographic region of the State. In setting apart the different regions no attempt has been made to determine exact physiographic boundaries. This is rendered unnecessary for the present purpose by the wide dispersal of the stations. From this point of view the Sierra Nevada is perfectly distinct from the Interior Valley, the southeastern desert from that part of southern California west of the desert, etc. Frequencies have been computed and frequency polygons constructed, for seven groups of stations, as follows:

1. *Coast Range group.*—Nine stations, arranged in order of decreasing latitude.
2. *Sierra Nevada group.*—Ten stations divided into two subgroups separated by the contour of 2,600 feet, each subgroup comprising five stations arranged in order of increasing altitude.
3. *Central Valley group.*—Twelve stations arranged in order of decreasing latitude.
4. *Coastal group.*—Four stations on the outer coast, as distinguished from those in group 1, and arranged in order of decreasing latitude.
5. *Northern Hill and Mountain group.*—Two stations.
6. *Southern California group.*—Four stations arranged in order of decreasing latitude.
7. *Southeastern Desert group.*—Two stations.

2. *Discussion of the frequency polygons.*—In the polygons each tenth of an inch horizontally represents 5 inches of rainfall and vertically 2 per cent of frequency. Thus each polygon shows percentage frequency of seasonal total rainfalls by 5-inch groups, the number of columns being an approximate measure of the range of seasonal amounts which may be expected in 100 years, while a rough indication of the degree of variability of the rainfall is afforded by the symmetrical or other arrangement of the columns on either side of that which represents the group of maximum frequency. In illustration of this last point the figures for Emigrant Gap (upper Sierra Nevada group) and for Placerville (lower Sierra Nevada group) may be compared. Emigrant Gap experiences seasonal rainfalls ranging through 16 groups from the 15–20 inch to the 90–95 inch. However, 85 per cent of the seasonal totals range through the 40 inches between 30 and 70 inches. Placerville experiences rainfalls ranging through 12 groups from the 20–25 inch to the 75–80 inch, but 88 per cent of the seasonal totals range through the 35 inches between 25 and 60 inches. In other words, the range of seasonal totals, leaving out of account the very large and the very small totals, is roughly the same at both stations. But inspection of their respective polygons shows striking differences in the distribution of frequencies. For Emigrant Gap, barring the 15 per cent of very large or very small totals, the remainder is composed of considerable frequencies of widely different rainfall amounts. Thus, seasonal totals of 30–35, 55–60, and 65–70 inches are equally frequent (12.5 per cent each). The most frequent total, that of 50–55 inches, is only 2.5 per cent more frequent than the totals just named. In contrast to this condition, at Placerville the group of most frequent occurrence is the 35–40 inch, with 17 per cent, the group next above and below having 14 per cent, the next above and below these, respectively, 12 per cent—a strongly symmetrical distribution. Hence at Placerville the frequencies decline consistently as the totals become both greater than and less than the most frequent total, while at Emigrant

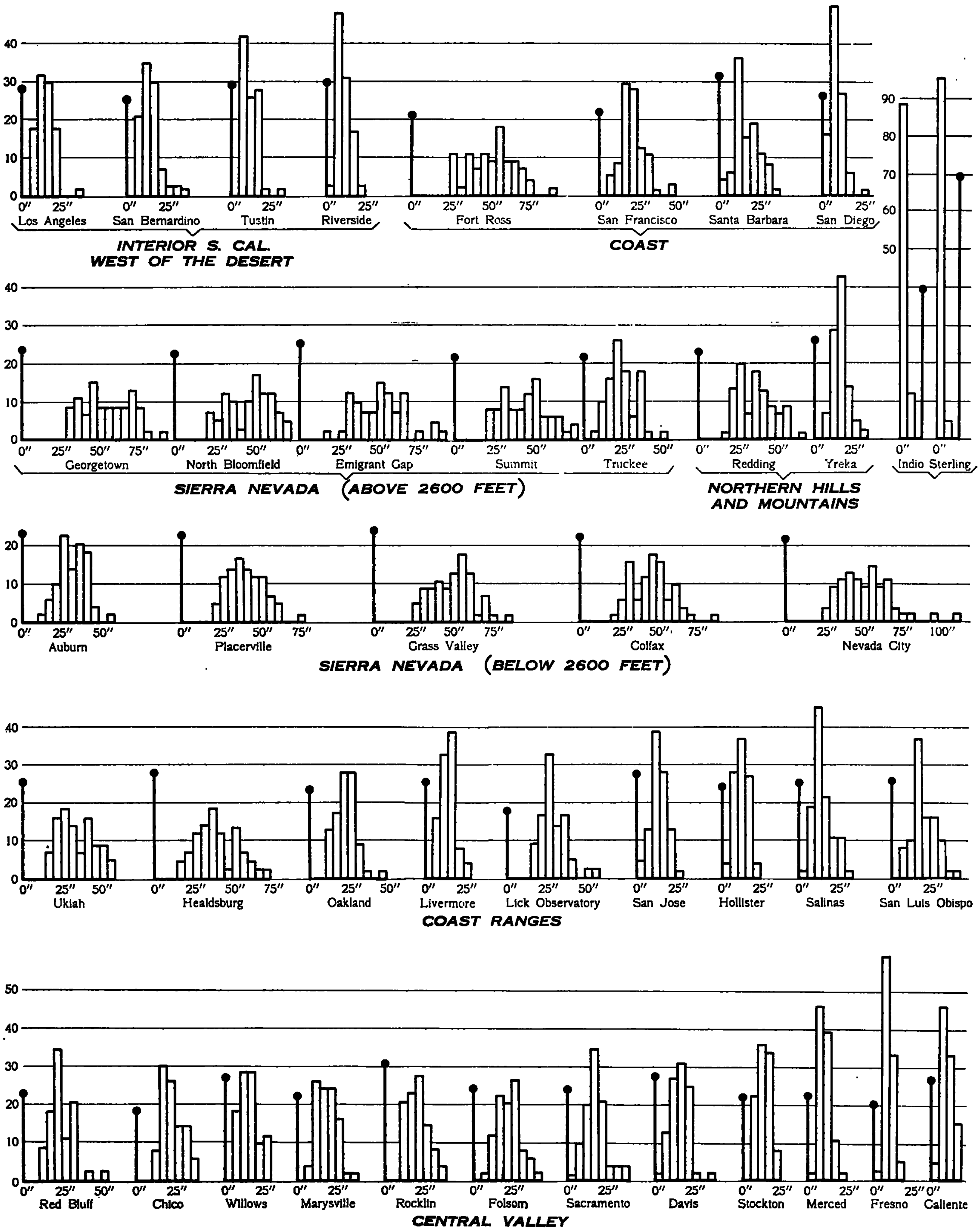

FIG. 7.—Frequencies of rainfall by 5-inch intervals for groups of stations having records of 40 seasons or over, the period covering the full record in each case and usually ending 1919-20

Gap both the very large and the very small totals are of about equally frequent occurrence.

3. *Frequency of rainfall percentages by 5-inch groups versus mean seasonal rainfall departures in percentages of the seasonal average rainfall.*—Combined with the frequency polygons of Figure 7 are graphic representations of the mean departures at the same stations. The dots at the tops of the heavy vertical lines erected at the zero point of the rainfall scale for each polygon indicate the mean seasonal departure in percentage of the average seasonal rainfall at the respective stations.

It is appropriate in this connection to call attention to the fact that the mean departures in percentages are not related to the range of the rainfall groups. That is to say, if we think of the changeableness of seasonal rainfalls in terms of the range of the actual amount recorded, then certain stations have a highly variable rainfall, as, for instance, Emigrant Gap or Nevada City. But if we think of it as expressed in terms of the mean departures in percentages of the seasonal average, then these stations have but moderate changes from season to season in comparison with many other stations in California. An extreme case, and therefore a useful one for illustration, is that of Sterling, in the Imperial Valley. Here a minimum variability in terms of spread of rainfall by 5-inch groups is coincident with a maximum variability in terms of percentage departures from the seasonal average.

4. *Relation between the magnitude of the rainfall averages and the number of rainfall groups.*—By way of contrast to the above, it may be noted that, broadly speaking, diminishing means of rainfall connote diminishing ranges of the individual seasonal amounts. To show approximately what this relation is, the dot chart of Figure 8 has been prepared, in which the number of rainfall groups at the 40-year stations used above are given as abscissae, and the mean rainfalls for 25 seasons at these stations as ordinates. The general rule, obviously, is true only within rather wide limits. For a given spread of rainfall groups there is a rather wide range in the seasonal mean rainfalls. Thus the stations having a spread through nine groups show rainfalls that vary from 15 to 37 inches. Likewise, for rainfalls of the same general magnitudes there are rather wide differences in the spread of the groups. Thus, the means which approximate 15 inches occur at stations which have a spread of the groups varying from 5 to 9.

It is probably true that neither one of these ways of expressing the vagaries of seasonal rainfall at a given place is adequate from all points of view. To the irrigation engineer, both the frequencies of stated amounts and the mean departures are of great significance, since his problem is partly one of the storage capacity of reservoirs in relation to successions of "wet" and "dry" years. Still more important is the distribution in time of the occurrences on which the frequency computations are based. The relation of this distribution to mean departures, the distribution being stated in terms of mean seasonal variability, will be briefly discussed in the section on "The Mean Variability of Precipitation."

5. *Agriculture and the frequency distribution of rainfall.*—A discussion of the relations between the facts shown by Figure 8 (dot chart) and the influences on agriculture of the frequency distribution of the seasonal rainfalls about the means is beyond the scope of this paper. The problem of what constitutes a deficient or an excessive seasonal rainfall is clearly a highly complex one. So far as the writer is aware, there is no discussion of it in print, except in the form of isolated and unrelated instances of the relation between a given crop and rainfall. It may be noted that beans in southern California are grown commercially year after year without irrigation under rainfalls of about 10 inches. Therefore for them 10 inches is not a deficient rainfall. The same amount in the nonirrigation decidious fruit belt of the Sierra foothills would be ruinous. Adequate discussion of the problem would deal with the infinitely variable relations between the water requirements of crop plants and precipitation, evaporation, soils, etc. From the point of view of nonirrigation agriculture, frequencies of occurrence of given amounts and the range within which they vary are likely to be more important than mean departures.

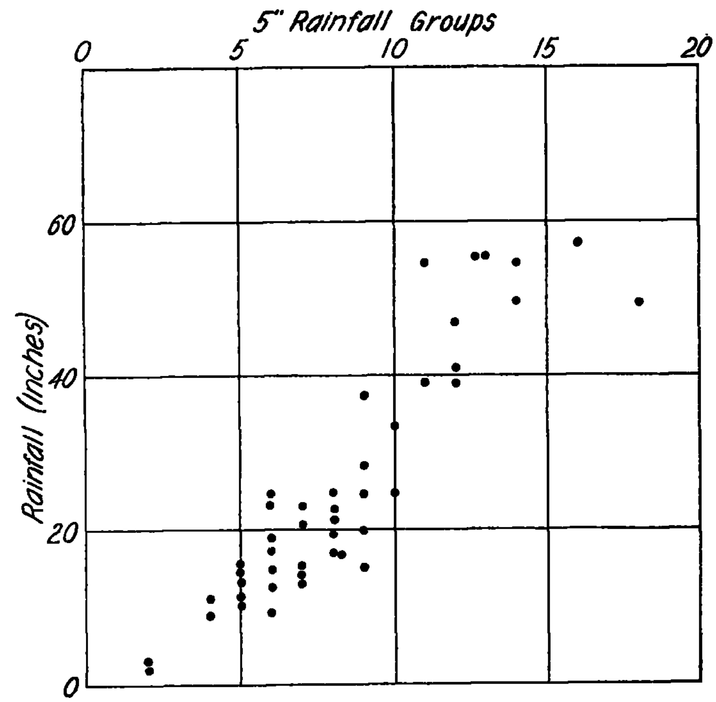

FIG. 8.—Relation between the numbers of 5-inch rainfall intervals (40 seasons or more) and the averages of rainfall (uniform period of 25 seasons)

In order that a certain amount of detailed information may be available regarding the frequencies of occurrence of given seasonal amounts of rainfall in terms of the percentages of the average amounts, the frequency polygons of Figure 9 have been prepared. The data from 42 stations having records of 40 seasons or more have been used. In the figure the percentages of normal are divided into 10-per cent groups, a 95–100 per cent group being that of least departure from the average, and the groups being arranged in order toward the lower and higher percentages.

The procedure in arriving at the percentages indicated was as follows: First the frequency of each percentage group for the whole period of each group was found. These records being of various lengths, with a mean length approximating 50 seasons, the actual frequencies were converted to the 50-season basis by proportion. This was done so that the polygons for the individual stations, besides indicating the conditions for that station, would also be comparable with the polygons for all the other stations of the list. This comparability is not perfect, however. In the conversion, fractional frequencies had to be discarded in the process of stating the frequency of a given percentage to the nearest whole number. Hence it is that a count of the blocks in many of the polygons would show numbers somewhat above or

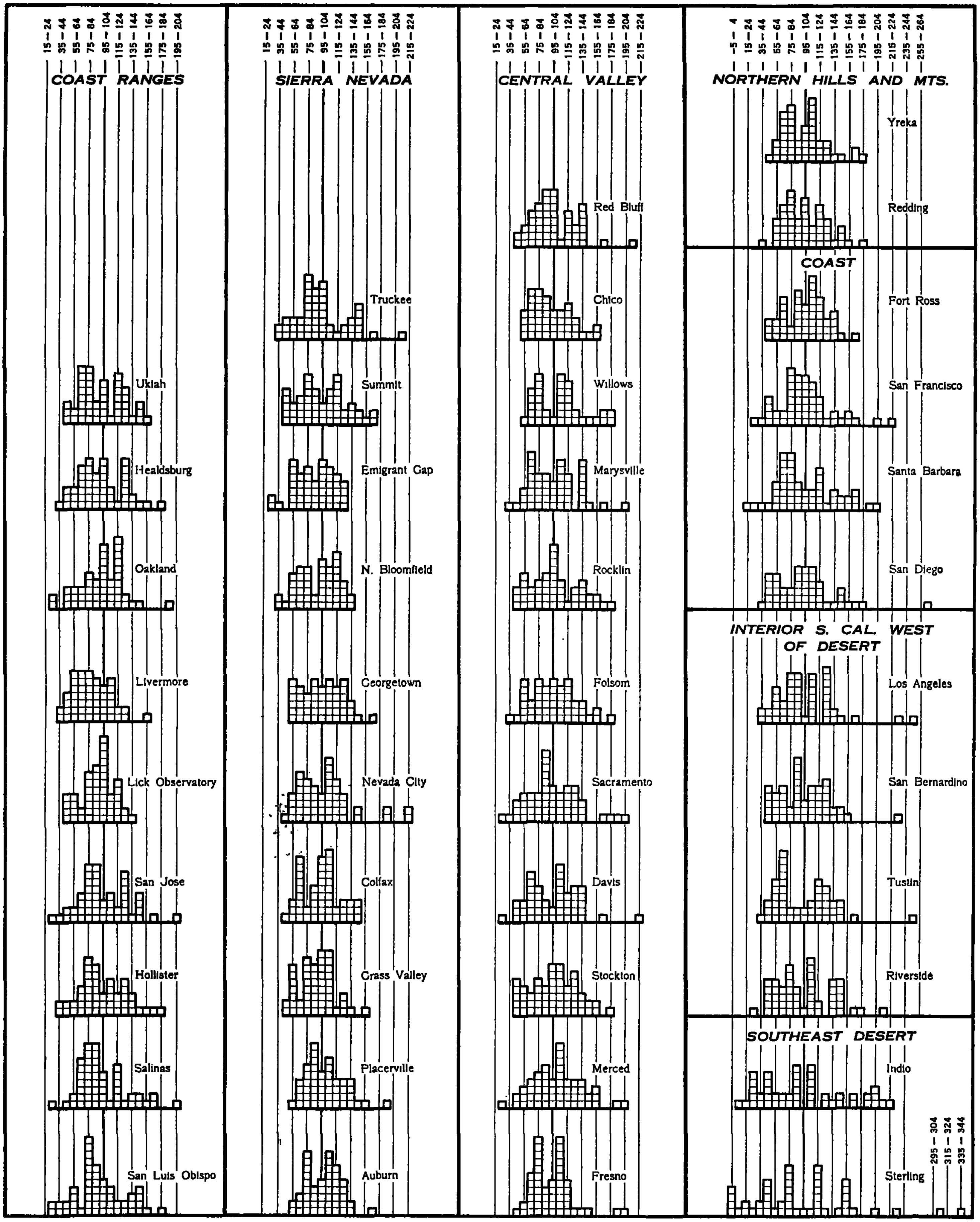

FIG. 9.—Frequency distribution of seasonal rainfall about the average, at 42 stations having not less than 40 seasons of record ending 1919–20. The frequencies are adjusted to a uniform 50-year period. The rainfalls are expressed in groups of percentage departures from the normal. From the "normal" group at top of figure, a heavy vertical line passes through the "normal" group in each column of polygons

below 50. It is believed this feature does not seriously impair the value of the figure.

It is not the intention to go into a complete discussion of the multitude of facts revealed by the polygons. Reference to their outstanding features as a whole would include mention of the extraordinary differences in the distribution of the frequencies, ranging from approximate symmetry about the modal frequency to complete lack of symmetry. Noticeable also is the rarity with which the most frequent seasonal rainfall coincides with the average rainfall (8 cases out of 42). The tendency is for this most frequent rainfall to lie considerably below the average—some 20 to 25 per cent, roughly speaking. This fact suggests that from some points of view a statement of the "average" rainfall of a place may be quite misleading. In those cases in which the frequencies are most symmetrically distributed about the mode, especially if this is accompanied by a rapid decrease of the frequencies on either side of it, a knowledge of what percentages are most frequent, next most frequent, etc., would undoubtedly give a more vivid and truer picture of the conditions.

Another aspect of the data for the same 42 stations is presented in Table 9. Therein are given, first, on the basis of the whole length of record at each station, the frequencies of departures within stated percentages of the average rainfall (either plus or minus) as adjusted to the uniform 50-year period; second, these frequencies converted into percentages frequencies, which in this case was very simply done by multiplying the adjusted frequencies by two.

TABLE 9.—*Frequencies in 50 seasons of departures (either plus or minus) within limiting percentages of the average seasonal rainfall at 42 stations having records of 40 seasons or more ending 1919–20, the frequencies being adjusted to the uniform 50-season basis*

Stations	Full length of record (seasons)	Limiting departures (per cents)				Percentage of cases			
		15	25	35	45	15	25	35	45
Ukiah	43	10	25	38	41	20	50	76	82
Healdsburg	43	15	23	36	41	30	46	72	82
Oakland	46	17	32	37	41	34	64	74	82
Livermore	49	17	26	35	42	34	52	70	84
Lick Observatory	42	24	37	41	46	48	74	82	92
San Jose	46	15	25	36	39	30	50	72	78
Hollister	46	15	26	35	40	30	52	70	80
Salinas	47	15	30	37	41	30	60	74	82
San Luis Obispo	51	16	29	32	39	32	58	64	78
Auburn	49	18	33	41	45	36	66	82	90
Placerville	40	21	31	39	44	42	62	78	88
Grass Valley	45	25	34	39	47	50	68	78	94
Colfax	50	24	28	40	46	48	56	80	92
Nevada City	56	18	30	41	45	36	60	82	90
Georgetown	47	17	25	36	45	34	50	72	90
North Bloomfield	42	15	29	39	46	30	58	78	92
Emigrant Gap	40	17	28	37	44	34	56	74	88
Summit	50	13	27	33	39	26	54	66	78
Truckee	50	17	27	32	38	34	54	64	76
Red Bluff	43	17	28	36	45	34	56	72	90
Chico	49	14	26	36	42	28	52	72	84
Willows	41	10	23	30	33	20	46	60	66
Marysville	49	16	26	34	43	32	52	68	86
Rocklin	47	18	23	29	38	36	46	58	76
Folsom	49	16	28	34	43	32	56	68	86
Sacramento	71	19	28	37	44	38	56	74	88
Davis	48	13	22	34	42	26	44	68	84
Stockton	53	18	27	36	43	36	54	72	86
Merced	48	19	28	36	39	38	56	72	78
Fresno	42	20	36	43	46	40	72	86	92
Yreka	43	17	28	38	42	34	56	76	86
Redding	45	14	28	38	43	28	56	76	86
Fort Ross	45	21	29	38	45	42	58	76	90
San Francisco	71	20	32	35	39	40	64	70	78
Santa Barbara	53	10	24	33	40	20	48	66	80
San Diego	70	18	25	29	35	36	50	58	70
Los Angeles	43	15	29	40	47	30	58	80	94
Tuskin	43	7	15	30	39	14	30	60	78
San Bernardino	50	17	24	35	41	34	48	70	82
Riverside	42	13	22	26	36	26	44	52	70
Indio	43	12	14	18	21	24	28	36	42
Sterling	42	3	17	20	21	6	34	40	42

This table in graphic form appears in Figure 10. In it the height of the column for a given limiting percentage departure from the seasonal average of precipitation represents the frequency (in per cent of the total number of cases) with which that limiting percentage occurs. Thus Ukiah (upper left corner of the figure) on the 50-season basis had in 20 per cent of the seasons, departures, either plus or minus, of 15 per cent or less; in 50 per cent of the seasons departures not over 25 per cent; in 76 per cent of the seasons not over 35 per cent either way from the average seasonal rainfall; and in 82 per cent of the seasons, departures not over 45 per cent.

A general interpretation of the columns for any station is as follows: The shorter the column under any limiting departure the greater are the frequencies left for representation by the other columns, either by one of the four shown, or by others beyond the limiting 45 per cent. Comparison of the extreme cases in the Los Angeles and Sterling graphs will make this clear. (See fourth group from top of sheet). At Los Angeles, departures of more than 45 per cent from the seasonal average are extremely rare (but 6 per cent of the seasons), while at Sterling they are extremely frequent (58 per cent of the seasons). Comparing Los Angeles with, for instance, Lick Observatory, one sees that departures beyond 45 per cent are about equally frequent, but that departures beyond 25 per cent are much commoner at Los Angeles than at Lick Observatory.

To give a regional arrangement of the graphs in Figure 10 the following scheme is used: Stations in the top line are in the Coast Ranges and arranged in order, left to right corresponding to the direction NW. to SE.; in the second line, Sierra stations stand, left to right, from lower stations on the west over the summit to Truckee in order of altitude; in the third line, left to right, are stations from NW. to SE. in the Interior Valley; in the fourth line, from the mountain and hill country of the north via the coast to southern California and into the desert; in the fifth line, a cross section of the State from San Francisco to Truckee. Lines joining the tops of columns for equal limiting departures are to guide the eye in making comparisons.

Much might be written on the details shown by the figure; the following points are perhaps of principal interest:

Top line.—The apparent regional change longitudinally in the Coast Ranges of the limiting departure of 15 per cent; the lack of system in the 25 per cent limiting departure; the strong contrast between Lick Observatory and all the other stations of the group, as pointed out in another connection.

Second line.—The shifts of frequency of the 15 and 25 per cent limiting departures with altitude across the Sierra.

Third line.—The contrast between Willows (a west-side valley station) and the east-side valley stations.

The striking rise of frequency of the 25, 35, and 45 per cent limiting departure between Merced and Fresno, suggesting a marked increase in the reliability of the rainfall from NW. to SE. in that region.

Fourth line.—The striking shifts in the frequencies of all departures between Los Angeles or Tustin near the coast into the desert.

Fifth line.—The suggestion, from the change in the heights of the 25, 35, and 45 per cent columns, that the frequencies of these departures may in some way be related to altitude of station and to the rainfall profile across the Sierra. It will be observed that the maximum

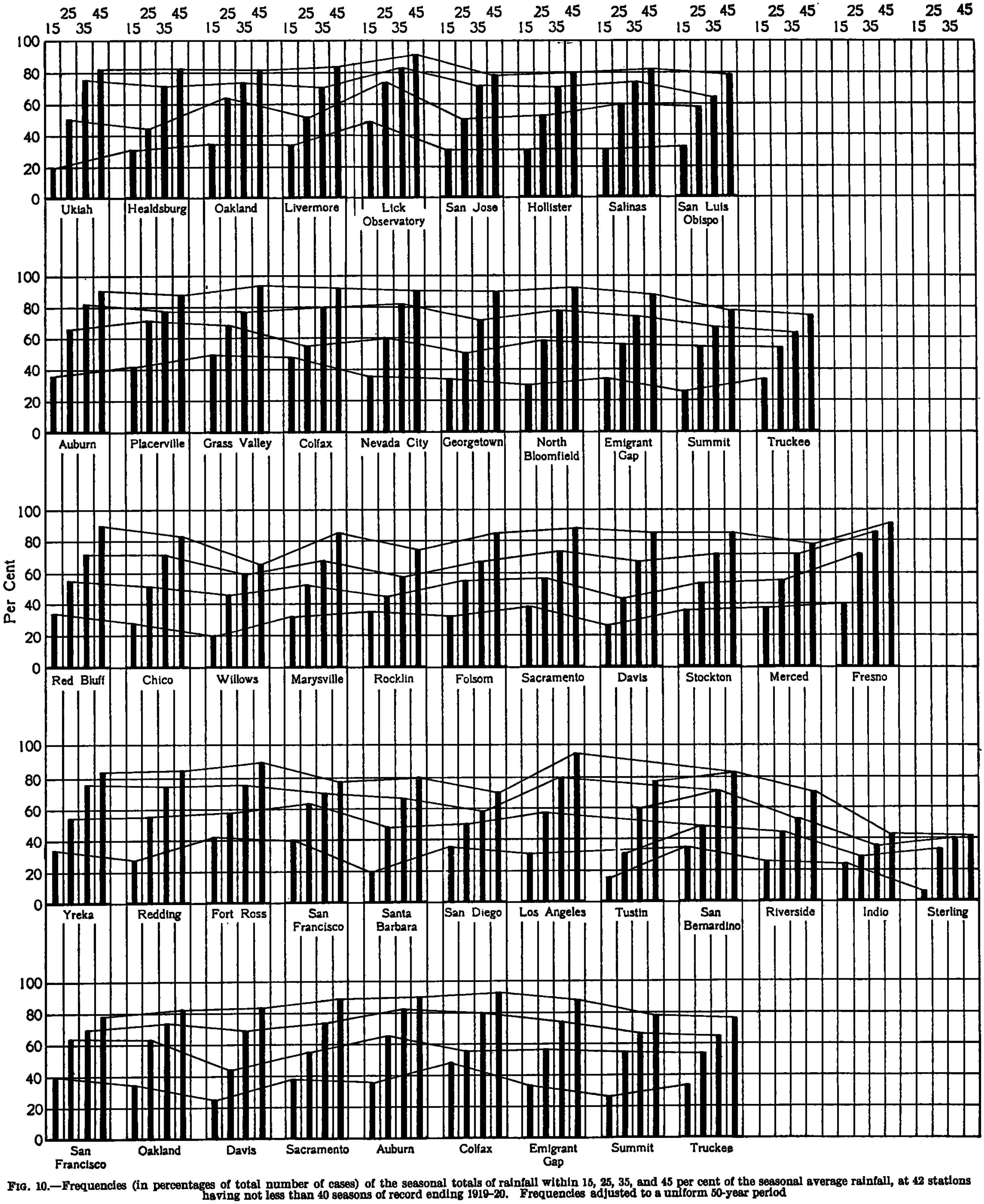

FIG. 10.—Frequencies (in percentages of total number of cases) of the seasonal totals of rainfall within 15, 25, 35, and 45 per cent of the seasonal average rainfall, at 42 stations having not less than 40 seasons of record ending 1919–20. Frequencies adjusted to a uniform 50-year period

frequencies of all these limiting departures occur below the level of maximum rainfall, Colfax being at 2,421 feet, and the maximum rainfall at approximately 5,000 feet.

VII. THE MEAN VARIABILITY OF PRECIPITATION IN CALIFORNIA

1. *Definition of "variability" as here used.*—Following established precedent the terms "departure" and "variability" have heretofore in this paper been used interchangeably, variability signifying what is, strictly speaking, departure; that is, deviation from the mean or average. If, however, average seasonal variability be defined as the average of the differences between successive seasonal totals of precipitation regardless of sign (i. e., regardless of whether the differences represent increases or decreases from one season to the next), and if a comparison of these averages with the average seasonal departures be made, it will be evident that very important practical consequences ensue from the varying relations of departure to variability. As a basis for a brief discussion of this point, the average seaonal variability of rainfall in terms of percentage of the seasonal average rainfalls for 82 stations has been included in Table A. But, as has been pointed out in another connection, the shorter the period the more dubious becomes the value of computing such items as departures, variabilities, etc. Hence in the following section 2 the discussion is based only upon the variabilities at stations having 25 seasons of record.

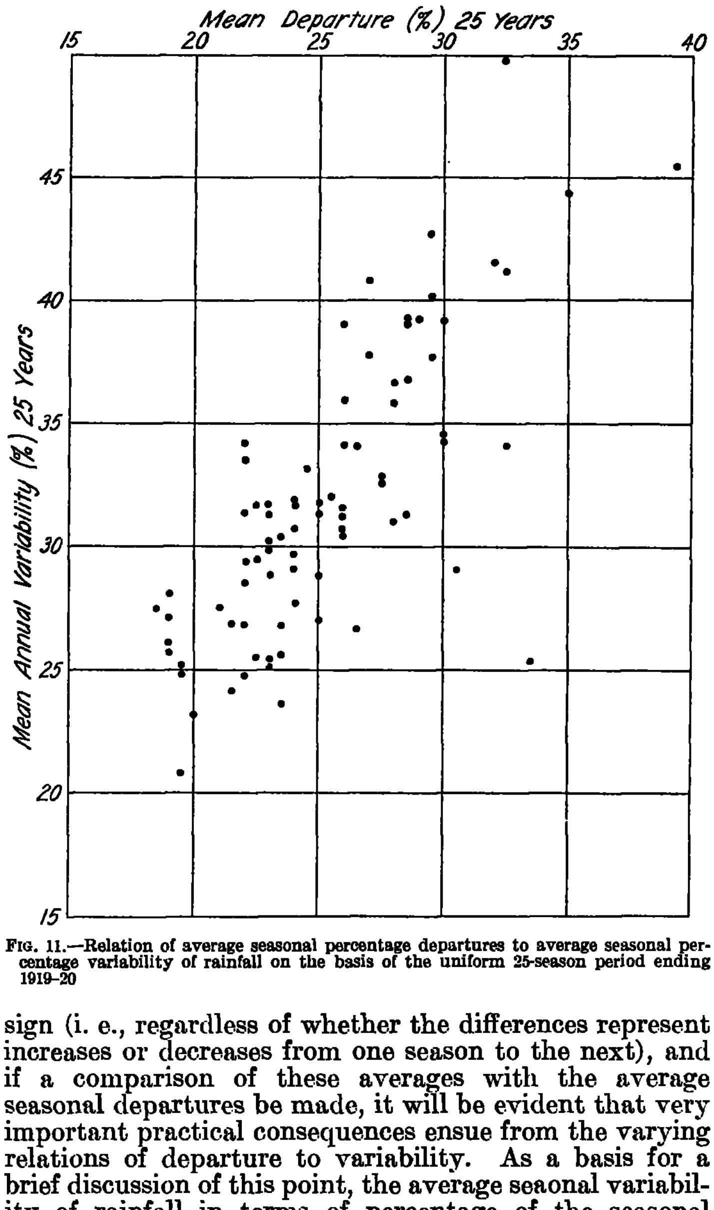

FIG. 11.—Relation of average seasonal percentage departures to average seasonal percentage variability of rainfall on the basis of the uniform 25-season period ending 1919–20

2. *Relations between variability and departure.*—The dependability of rainfall expressed in this manner in a very general way resembles that given in terms of the mean departures from the seasonal averages. But there are some important deviations from this general condition. To show to what extent this is true for California, Figure 11 has been prepared, in which the percentage variabilities are given as ordinates and the percentage departures as abscissae. Vertical and horizontal scales have been made alike in order to preserve the proper dispersion of the two sets of percentages in respect to each other. It is clear that there is a tendency toward a straight line relation between the two sets of values, but that the relation is not close. There are many cases of large departures coincident with small variability and vice versa, and for a given variability departures occur through a rather wide range of values and vice versa. The most significant thing about the relation is that large average departures do not necessarily connote large average variabilities. The occurrences of the departures may take place in groups (a feature which unfortunately can not be seen from the dot chart)—groups in which the departures have the same sign and a high value, this group eventually giving way to one having the opposite sign and equally high value, the change taking place from one season to the next. In such a case the departure is large and the variability relatively small. Rapid oscillations between large excess and large deficiency mean, of course, high values of both departures and variabilities. Equally rapid shifts from small excess to small deficiency give small departures and small variabilities. The complexity of the relations is obvious.

3. *Relation of variability and departure to California water problems.*—For California the ultimate success or failure of water-storage projects depends on how adequate are the preparations made for meeting the infinite variations in the interrelations of these two factors. It should be emphasized that high mean departures entail very different practical consequences according to whether they coincide with high or with low mean variabilities. With high variability rainfall deficiency of one season will in general be soon compensated for by excess in another. Hence reservoir capacity need not be larger than that necessary to care for the demands through two or three seasons. With low variability, however, a high mean departure indicates the tendency for several "dry" or several "wet" years to occur consecutively, in which case the capacity of reservoirs must be sufficient not only to meet current demand but to conserve the excessive receipts of water of the wet periods to meet the requirements during the periods of deficiency. The areal distribution of mean variabilities is set forth on the map in Figure 12 and will be discussed in the following section 4.

4. *The regional distribution of average variabilities in California.*—With 82 stations distributed irregularly over a region like California, a thoroughly satisfactory mapping of variabilities is, like the mapping of departures already discussed, impossible. If, however, we select 10 per cent as the difference between variability values for which isograms shall be drawn, it becomes possible to differentiate in a general way certain large regions. The process involves ignoring, for mapping purposes, the variabilities at some stations which are not in accord with those that are characteristic of the surrounding regions. Thus, in the area labeled "Under 30 per cent," will be found an occasional value over 30 per cent, etc. Interpreting the distribution of the values thus somewhat liberally, it is apparent that the State may be divided into the following regions:

(1) The larger part of the Sierra Nevada, excluding the foothills, appears to have an average seasonal variability of over 30 per cent.

(2) West of this lies a long belt which includes most of the foothills and a considerable strip along the eastern side of the Interior Valley, where a variability under 30 per cent is characteristic. This belt seems to be continued in a fan-shaped area northward and northeastward into the semiarid region of northern California.

(3) West of No. 2 variabilities increase, so that a large part of the eastern Interior Valley and all of its western part, together with a considerable portion of the Coast Range country north of San Francisco Bay, show variabilities well over 30 per cent.

Between region 3 and the coast one may distinguish two fairly definite regions, as follows:

(4) In the northern Coast Ranges, in an area which includes perhaps the western third of them, variabilities are considerably lower than they are east of this region. There is also an apparently well-marked increase in variability from about 20 per cent in the northern part of the area to about 30 per cent around San Francisco Bay. Tracing the figures still southeastward within the Coast Ranges, one finds them rising irregularly to well over 40 per cent in the ranges north of Monterey Bay, decreasing to somewhat under 40 in the region east of the Bay, then rising to over 40 in the southern Coast Ranges.

(5) The southern Coast Ranges average distinctly higher in variability than the northern, the magnitude of it increasing southeastward and eastward into the high values of the southeastern desert.

(6) The southeastern desert is characterized by an extraordinary range of variabilities, including the unaccountably small variability at Lone Pine north of Owens Lake and the maximum value at Bagdad.

(7) Southern California west of the desert is, in the matter of average seasonal variabilities, clearly to be distinguished from the forbidding country at its back. Its variabilities largely stand midway between those of the desert rainfall and those of the fairly dependable rainfall in central and northern California. An exception to this condition is seen in the country north and east of San Diego, where the variabilities appear to be of the same order as those in central and northern California.

CONCLUSION

The foregoing material would seem to suggest that the most important subjects for future studies of this type on California rainfall should be:

1. With the frequency polygons here presented as a point of departure, the determining of the facts regarding (*a*) the relation of the most frequent seasonal totals of rainfall to the "normal" or arithmetical average amount; (*b*) the probabilities of occurrence of the most frequent amount; (*c*) the probabilities of occurrence of the "normal" amount; (*d*) the most probable seasonal amounts above and below the "normal."
2. The duration of periods (one or more seasons) of rainfall above and below the normal.
3. The averages of seasonal rainfall during periods of excess and deficiency.

The basis for such studies as those outlined above is constantly growing better. At this time (end of the 1924–25 rainfall season) five seasons in addition to those used in this paper have increased the value of the record. Many stations formerly in the "short-period" group now have moved into the "long-period" group and have data for 25 seasons or more. What is perhaps of greater importance is the increase in the number of stations having at least 10 seasons of record. These should, by filling many a gap in the *réseau* of stations, greatly aid in any future work on the problem.

NOTES, ABSTRACTS, AND REVIEWS

INTERNATIONAL COMMISSION FOR THE INVESTIGATION OF THE UPPER AIR

[Reprinted from Nature, no. 2898, May 16, 1925, pp. 781–782]

A meeting of the International Commission for the Investigation of the Upper Air was held in London on April 17–22.

At the meeting of the commission in Bergen in July, 1921, the commission adopted the view that the international publication of the results of the investigation of the upper air ought to be resumed, and that an international bureau should be established and supported by contributions from the different States, so that the preparation and compilation of the results should not in future be done at the sole cost of the national service which undertook the work. Unfortunately, it did not prove practicable, in the stringent economic times which followed the meeting of 1921, to obtain the funds which were necessary to carry out the recommendations of the meeting at Bergen. In consequence of this, Prof. V. Bjerknes, who had been president of the commission, resigned his position, as he could not spare the time from his purely scientific work to carry out unaided the large amount of work involved in the preparation and publication of the international upper air results. Sir Napier Shaw, then president of the International Meteorological Committee, took over the presidency of the commission at the request of the members.

Various methods for securing the object of an international publication of upper air results have been considered or tried experimentally since that time. No satisfactory solution of the question has been achieved. A short meeting of the commission was held after the international conference at Utrecht in 1923 at which the results of the inquiries were briefly surveyed, and a preliminary discussion took place on the most appropriate form for an international publication.

In 1924, at the meeting of the International Union for Geodesy and Geophysics at Madrid, the union voted the sum of 500*l*. toward the expenses of publication of a specimen volume of upper air data, and Professor van Everdingen, the director of the Meteorological Institute of Holland, promised a contribution of about 100*l*. for the same purpose.

The meeting of the commission in London was concerned primarily with the consideration of the form which the specimen publication should take. Representatives from the following countries attended: France, Captain Wehrlé; Germany, Professor Hergesell; Great Britain, Sir Napier Shaw, Sir Gilbert Walker, Capt. C. J. P. Cave, Lieut. Col. E. Gold, Mr. L. H. G. Dines, Mr. L. F. Richardson; Holland, Professor van Everdingen, Professor van Bemmelen; Italy, Lieut. Col. Matteuzzi, Professor Gamba; Norway, Doctor Hesselberg; Russia, Doctor Molchanoff; Spain, Colonel Meseguer. The meetings of the commission were divided

FIG. 12.—Isograms of average seasonal variability of precipitation in percentage of the seasonal average rainfall, for stations having 25 seasons of record ending 1919–20